THE INSTITUTE OF PHYSICS
47 BELGRAVE SQUARE, LONDON, S.W.1.

BULLETIN

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The Bulletin is not intended for general circulation : your copy should not therefore be passed to a library.

APPOINTMENTS VACANT

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

The British Thomson-Houston Company Ltd., has a vacancy in its Research Laboratory at Rugby for a qualified **Electrical Engineer** or **Physicist** for work on radio interference problems. The work covers investigation of the mechanism, measurement and suppression of radio interference over a wide and interesting range of sources. Applicants should write to the Director of Research, British Thomson-Houston Company Ltd., Rugby, giving their age and qualifications, and quoting the reference RIS.

The British Petroleum Company Limited requires for research and development in geophysics at its Research Station in Nottinghamshire, a **Physicist** with honours degree and at least 2 years' postgraduate research experience. Some knowledge of electronics, particularly in its application to field instruments, is desirable. Salary according to age, experience and qualifications. Good Pension Scheme. Write, stating age and giving full details quoting H.3337 to Box 7555, c/o 191 Gresham House, London, E.C.2.

Australia — University of New England
Armidale, New South Wales

Applications are invited for appointment as **Senior Research Fellow in Physics.**

The Fellow will be required to undertake a programme of experimental or theoretical research, preferably but not necessarily in the field of Ionization and Discharge Physics or of Solid State Physics. Applicants should give an outline of the work they wish to do.

The appointment will be initially for three years with the possibility of extension for a further two years ; salary will be at the rate of £A1600 per annum.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

The closing date for the receipt of applications, in Australia and London, is June 27, 1955.

The National Physical Laboratory require **Scientific Officer** for work on photometry and colorimetry with particular emphasis on physical methods and problems connected with the primary and secondary standards of light and the colour temperature scale. Qualifications : 1st or 2nd class hons. degree in physics. Inclusive annual remuneration for a 45½ hour week within the range : £532 – 955 (men) ; £532 – 858 (women). Women's pay subject to improvement under the Equal Pay Scheme. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A176/5A. Closing date 2nd July, 1955.

Investigators required to study problems in physical metallurgy and in instrumentation of metallurgical processes. Initial salary up to £900 per annum according to qualifications and experience. Write : The Secretary, **British Non-Ferrous Metals Research Association**, 81-91 Euston Street, N.W.1.

Principal Scientific Officer (Min. age 31) required by **Ministry of Supply** at London H.Q. to lead a section responsible for initiating and supervising research and development in design of aircraft flight instruments. Duties include close liaison with Service departments, Experimental Establishments and contractors. 1st or 2nd class honours degree or equivalent qualification in Electrical or Mechanical Engineering or Physics. Postgraduate research experience required and experience in leading a section desirable. Industrial experience of the development of aircraft equipment an advantage. Salary within range £1,185 – £1,570 (Superannuable). Women somewhat less. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting Ref. C274/5A. Closing date June 29, 1955.

Engineers and Physicists.

Ferranti Limited in their new Laboratories are engaged in a programme of electronic development of great industrial importance. The work involves the use of digital computors to control machines and industrial processes and covers a wide and expanding field of application, offering long-term interest to those engaged in it.

Development activity for these projects is taking place in the field of electronic circuitry (including pulse technique), digital computers, magnetic recording and servomechanisms. Engineers and Physicists having experience as well as interest in one or more of these subjects are invited to apply.

The appointments are permanent and offer full scope for initiative in an expanding organization. A salary commensurate with the qualifications required will be paid. Staff pension scheme. Application form will be sent on request (quoting Ref. 40/EP/AL) to the Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh, 5.

W. Edwards & Co. (London), Limited, High Vacuum Engineers, Manor Royal, Crawley, Sussex, have the following vacancies in their Research Laboratory :—

Vacuum Physicist (Qualified Physicist or equivalent) required for research and development of instruments and apparatus, including optical, mechanical and ionisation devices. Previous high-vacuum experience a distinct advantage.

Physicist or **Chemical Engineer** (Graduate or equivalent) required for research and development on vacuum drying and allied problems. Must have laboratory experience preferably in vacuum or refrigerating fields.

Research Assistant (Graduate or equivalent) in vacuum deposition section. Work ranges from investigations into the properties and uses of vacuum evaporation and cathodic sputtered films, to development of new High Vacuum plant.

Low Temperature Research Assistant (Degree or equivalent in Engineering or Physics) for apparatus development. Experience in vacuum and/or handling of liquefied gases an advantage. Development aptitude and associated skills essential.

Commencing salaries offered are commensurate with age, qualifications, and experience and range from £600 to £750 per annum. Housing available if from London Area. Pensionable position. Write giving full details to the Personnel Officer.

(*Continued on page iii*)

James A. Jobling & Co., Ltd.,
makers of
"Pyrex"
Laboratory, Scientific and Oven-Table
Glassware

in planning extensive expansion of their manufacturing activities, require to augment their Management and Technical Staff and accordingly invite applications from :

(*a*) Honours Graduates with Engineering or Science degrees, under 30 years of age who consider themselves ultimately capable of achieving a senior executive position. Selected candidates will be given a comprehensive training in the various activities of the Company with a view to appointment at Junior Management level ;

(*b*) Honours or Pass Graduates with degrees in Physics or Mechanical Engineering, to take up appointments in the Research and Development Department. These vacancies offer wide scope and opportunities to young men having initiative and a broad outlook, with the possibility of transference to management positions.

In all cases a commensurate salary is offered. Contributory Pension Scheme. Write giving full particulars to Personnel Department, James A. Jobling & Co. Ltd., Wear Glass Works, Sunderland.

Mathematician required in connection with research and development of Scientific Instruments of wide variety. Applicants must have mathematics on the level of a good honours degree, and also some knowledge of physics.

Applications, stating age and qualifications, should be addressed to The Secretary, **Messrs. Barr and Stroud Limited,** Anniesland, Glasgow, W.3, under reference 724/T-15.

Large British Oil Company has vacancies for **geophysicists** on its exploration staff. Candidates should have an honours degree in physics with subsidiary mathematics and/or geology, but candidates with a general degree will be considered. The work involves delineation of underground rock structure by seismic, gravitational and magnetic techniques and offers considerable scope for men with initiative who are prepared to travel and to work abroad. Normal leave is four months after two years' foreign service.

When conditions permit, facilities are afforded for married men to have their families with them on foreign tours.

Basic salary is commensurate with age and experience, commencing at £870 for young, inexperienced graduates. Appropriate allowances are paid whilst on foreign service. Generous pension scheme.

Applications quoting F.107, should be addressed to Box 1223, c/o 191 Gresham House, E.C.2.

The British Petroleum Company Limited invites applications from young Graduates with a degree in Engineering, Physics, Mathematics or Natural Philosophy, to be trained as Petroleum Engineers. Training will last for approximately 2 years and will take place partly in the United Kingdom and partly overseas. On successful completion of the training, men will be posted as **Resident Petroleum Engineers** to exploration areas overseas. Age preferably not over 26, National Service obligations must have been fulfilled. Write stating age and full details of qualifications and experience quoting H.2089 to Box 7649, c/o 191 Gresham House, E.C.2.

Expansion in the programme of a S.W. London Company Manufacturing industrial instruments and controls requires **physicists, electrical** and **mechanical engineers** for development of new ideas in this field. Applicants to be of graduate status or equivalent professional qualifications. Two positions for seniors up to £1,500 p.a.—several years' experience of industrial or academic research required for these—but several vacancies exist for development engineers having relevant experience—salaries up to £1,200 p.a. Applicants should state age and past experience, qualifications to C.D.E. Box AV.78, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

A young graduate (male) in Physics is required to work at **Ilford Limited,** Watford, on the physical aspects of photographic problems, in particular those associated with the photographic effects of X-rays and γ-rays. Apply in writing to Research Director, Ilford Limited, Ilford, Essex.

THE ROYAL
TECHNICAL COLLEGE
GLASGOW
(In affiliation with the University)
Department of
Electrical Engineering

Lecturer in Electronics :—Applications are invited for this appointment, at a salary in the range of £650 × £50 to £1,350, with F.S.S.U. benefits, and commencing later than October 1. Candidates should possess a good Honours Degree in Electrical Engineering, and have had experience in Servomechanisms. The duties will include lecturing to undergraduate and postgraduate students, and participation in research activities. Further details and forms of application may be obtained from the Secretary.

Rhodes University
Grahamstown, South Africa

Applications are invited for the post of **Senior Lecturer in Physics** from September, 1955.

The salary scale is : £1050 × £50 – £1400 p.a. In the case of married persons only, a variable cost-of-living allowance, at present £294 p.a., is payable in addition. Previous experience and academic qualifications may be taken into account in fixing the commencing salary.

Full particulars and application forms may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

The closing date for the receipt of applications in South Africa and London, is June 30, 1955.

University of Otago
Dunedin, New Zealand

The University proposes to appoint a **Senior Lecturer** or **Lecturer in Physics** in order to fill the vacancy which has arisen by the appointment of Dr. A. G. McLellan to the Chair of Physics at Canterbury University College.

The salary range is for a Senior Lecturer, £1,092 8s. 0d. × £50 to £1,292 8s. 0d. p.a., and for a Lecturer, £892 8s. 0d. × £50 to £1,042 8s. 0d. p.a. Initial placing within these scales will depend on experience and qualifications.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

The closing date for the receipt of applications, in New Zealand and London, is July 15, 1955.

(*Continued on page v*)

PHYSICS IN INDUSTRY SERIES

THE MEASUREMENT OF STRESS AND STRAIN IN SOLIDS
A symposium (17*s.* 6*d.* ; *Members* 10*s.* 6*d.*)

THE ACCELERATION OF PARTICLES TO HIGH ENERGIES
A symposium (10*s.* 6*d.* ; *Members* 7*s.* 6*d.*)

CREEP OF METALS
By L. Rotherham, F.Inst.P.
(15*s.* 0*d.* ; *Members* 10*s.* 6*d.*)

INDUSTRIAL MAGNETIC TESTING
By Prof. N. F. Astbury, F.Inst.P.
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By W. Hume-Rothery, O.B.E., F.Inst.P., F.R.S.
J. W. Christian, A.Inst.P., and W. B. Pearson
(50*s.* 0*d.* ; *Members* 37*s.* 6*d.*)

MODERN MASS SPECTROMETRY
By G. P. Barnard, F.Inst.P.
(50*s.* 0*d.* ; *Members* 37*s.* 6*d.*)

X-RAY DIFFRACTION BY POLYCRYSTALLINE MATERIALS
Technical Editors : H. S. Peiser, F.Inst.P., H. P. Rooksby, F.Inst.P. and Prof. A. J. C. Wilson, F.Inst.P.
(63*s.* 0*d.* ; *Members* 50*s.* 0*d.*)

PHYSICS OF FIBRES
By H. J. Woods, F.Inst.P. (*to be published*)

THE INSTITUTE OF PHYSICS

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NOTICES TO MEMBERS

Honorary Fellow

In accordance with By-law 9 the Board nominated Sir James Chadwick for election to Honorary Fellowship and following the postal ballot Sir James was declared duly elected at the Annual General Meeting on May 17. Sir James Chadwick, now Master of Gonville and Caius College, Cambridge, was formerly Lyon Jones Professor of Physics in the University of Liverpool ; he was awarded the Nobel Prize for physics in 1935. He has been a Fellow of the Institute since 1936.

The grade of Honorary Fellow is, by the By-laws, restricted to a total membership of not more than ten at any time and they are to be " distinguished persons intimately connected with physics or a science allied thereto whom the Institute especially desires to honour for exceptionally important services in connection therewith." The other present Honorary Fellows are Sir Edward Appleton, Sir Owen Richardson, Sir Frank Smith, Prof. A. M. Tyndall, and Prof. C. T. R. Wilson.

Proceedings of the Thirty-Fifth Annual General Meeting

The Thirty-fifth Annual General Meeting of the Institute was held on May 17 at 5.00 p.m. at the Institute's House. Mr. O. W. Humphreys (*Vice-President*) was in the Chair. A quorum being present, the Secretary read the notice convening the meeting. The Minutes of the previous Annual General Meeting held on May 18, 1954, and of the Extraordinary General Meeting held on December 15, 1954, were read and approved and were then signed by the Chairman.

Dr. A. J. Kennedy (*Fellow*) and Dr. D. H. Follett (*Fellow*), were appointed scrutineers for the ballot for election to the Board and for the election of an Honorary Fellow.

On the proposal of the Honorary Treasurer (Dr. S. Whitehead) seconded by Mr. G. R. Noakes (*Vice-President*) the accounts and balance sheets for 1954 were unanimously adopted. The Honorary Secretary (Dr. B. P. Dudding) moved the adoption of the report of

the Board for 1954 and this was seconded by Dr. K. A. G. Mendelssohn (*Fellow*) and carried unanimously.

Having received the report of the scrutineers the Chairman declared the following to be elected to fill the vacancies on the Board which will occur on September 30, 1955 :—

President : Sir John Cockcroft ;
Vice-President : Dr. W. H. Taylor ;
Honorary Treasurer : Dr. S. Whitehead ;
Honorary Secretary : Dr. B. P. Dudding ;
Ordinary Members of the Board : Dr. M. R. Hopkins, Dr. J. Taylor, Dr. J. M. A. Lenihan.

In the ballot for the election of three Ordinary Members, 310 ballot papers were received of which four were invalid. The voting was as follows :—

Dr. M. R. Hopkins	...	262
Dr. J. Taylor ...	...	238
Dr. J. M. A. Lenihan	...	221
Dr. L. R. G. Treloar	...	194

The Chairman declared that Sir James Chadwick had been elected an Honorary Fellow of the Institute.

Messrs. Knox, Cropper and Co. were elected auditors for the year 1955.

Votes of thanks were moved to the President, Honorary Officers and members of the Board, the Honorary Officers of Branches and Groups and the many bodies which have allowed the use of their rooms during the year for meetings. These were carried with applause.

British Nuclear Energy Conference

As a result of discussions over some months the Institutions of Civil, Mechanical, Electrical and Chemical Engineers and the Institute of Physics have formed a new organization for the consideration of developments in the technology of nuclear energy. This new permanent consultative body will be known as the British Nuclear Energy Conference. Its affairs will be controlled by a Board, which will consist of three representatives from each of the five professional institutions. Sir Christopher Hinton has agreed to serve as Chairman and Mr. A. McDonald (Secretary of the Institution of Civil Engineers) as Secretary. The three representatives of the Institute of Physics are Sir John Cockcroft (*President*), Mr. O. W. Humphreys (*Vice-President*), and Dr. H. R. Lang (*Secretary*).

The constitution of the Board of the Conference provides for deputies to representatives and the Institute's representatives' deputies are Dr. T. E. Allibone, Dr. J. V. Dunworth, and Mr. N. Clarke.

Among the activities of the Conference will be the holding of lectures and symposia on the technology of nuclear energy and its applications and the publication of a journal containing records of discussions, symposia and conferences arranged by the new body. This journal will be offered for sale ; members of the five constituent bodies will be entitled to the journal at reduced rates. Initially the journal will be published twice a year, but eventually it may be a quarterly.

A one day lecture symposium is being arranged for November and a second symposium will be held in March, 1956. Full details will be notified to Institute members later.

Institute recognition of Technical College "Sandwich" Courses

An article by Dr. J. Topping on page 129 of this issue discusses "sandwich" courses in physics that it is proposed to start in some of the larger Technical Colleges. Details of the courses to be offered by three Colleges have been submitted to the Institute's Membership and Examinations Committee which has also had the views of its Graduateship Examiners upon them. This Committee has recommended to the Board, which has accepted the recommendation, that the courses at these three Colleges should be recognized by the Institute and that successful students should be given complete exemption from the Institute's Graduateship Examination. The awards will probably be diplomas of the Colleges.

The Colleges concerned are Northampton Polytechnic, London, the College of Technology, Birmingham, and Acton Technical College, Middlesex. The Board is anxious to give every possible encouragement to the major Technical Institutions to develop courses and awards in physics that are of university degree standard, but are different from the courses for university degrees. As Dr. Topping points out in his article, the Board has stated in several published reports that, in its view, Technical Colleges have a distinctive contribution to make in the field of education in physics.

Table Plaque

Through the courtesy of Mr. Frederick D. Edwards, the Managing Director of W. Edwards & Company (London) Ltd., a small rhodium-plated silver plaque has been fixed to the Lecture room table recording the fact that this and the lectern were presented to the Institute by the members of the London and Home Counties Branch of the Institute.

Electronics Exhibition

The Tenth Annual Exhibition organized by the Northern Division of the Institution of Electronics will be held at the College of Technology, Sackville Street, Manchester, 1, during the period July 14 to 20, 1955. The exhibition will be open from 2 p.m. to 10 p.m on July 14, from 10 a.m. to 10 p.m. on July 15, 18, 19 and 20 and from 10 a.m. to 6 p.m. on July 16.

Programmes of the lectures and film show (post free 4½d.) will be available in June and catalogues (post free 2s.) will be on sale early in July. Tickets are obtainable, free of charge, from the Honorary Exhibition Organizing Secretary, Mr. W. Birtwistle, 78 Shaw Road, Rochdale, Lancs., or from any of the exhibitors. A stamped addressed envelope should be enclosed.

Polarization Microscopy and Optical Crystallographic Methods

A post-graduate summer school in Polarization Microscopy and Optical Crystallographic Methods is being held at the University of Leeds from September 5 to 16, 1955. The course will be in the Department of Inorganic and Structural Chemistry. It will provide basic training in the theory and use of the polarizing microscope for the study of crystals and other birefringent materials (e.g. fibres and cell walls), and in the applications of the instrument in various branches of science and technology. Enquiries should be addressed to the Secretary, Department of Adult Education and Extra-Mural Studies, The University, Leeds, 2.

Changes of Branch and Group Officers

Dr. R. W. Sillars (*Fellow*) has now become Chairman of the Manchester and District Branch, with a seat on the Board, in succession to Mr. W. J. Meredith who has served for four years.

Mr. M. E. Haine (*Fellow*) has been elected Chairman of the Electronics Group and is succeeding Mr. G. W. Warren.

The Midland Branch Honorary Secretary is now Dr. R. J. Wakelin (*Associate*) who has taken over from Mr. W. C. Hynd.

Dr. U. W. Arndt (*Associate*) has become Honorary Secretary of the X-ray Analysis Group in succession to Mr. E. J. W. Whittaker.

THE FUNDAMENTALS OF THERMODYNAMICS*

By Professor E. A. GUGGENHEIM, M.A., Sc.D., F.R.S.
(*University of Reading*)

When accepting the invitation to give a lecture on the "fundamentals of thermodynamics," I considered myself free to interpret the word "fundamentals" as I liked. I interpret it to mean not a formulation of the subject so abstract that only an expert mathematician can follow it, but to mean on the contrary the foundations or basis for a first introduction to the subject.

I will begin by stating my conviction that in a first introduction to thermodynamics no attention whatever should be paid to the historical development of the subject. There are at least half a dozen contributory reasons. First, the history of thermodynamics is a different subject from thermodynamics. Second, no one would think of teaching the history of, say, French before teaching French; similarly the history of thermodynamics should be taught after, not before, thermodynamics. Third, a historical development of reasonable length would almost certainly be incomplete; in particular there is the difficult question where to begin. Fourth, unless the teacher has himself done research on the history of thermodynamics his account of it is almost certain to be inaccurate; in particular the accounts usually given of Carnot's cycle bear little relation to Carnot's own exposition. Fifth, a historical development, if accurate, must be complicated; I need only remind you that the formulation of the second law preceded the formulation of the first law. Sixth, the development of the subject included obscure terminology now discarded; I need only mention the single example of the title of Carnot's classic "La puissance motrice du feu"; none of the words "puissance," "motrice" or "feu" has any part in a modern exposition of thermodynamics.

The most fundamental conception of thermodynamics is that of temperature and more especially that of constant temperature. Over and above work done on or by a system, a system can gain energy from its surroundings or lose energy to its surroundings according as its temperature is less or greater than that of its surroundings. Such an exchange of energy is called a flow of heat. It is important to make clear that heat, like work, is not a form of energy but a form of energy transfer. Heat is in fact a transfer or flow of energy resulting from a temperature difference.

The behaviour of almost any system is simplest when its temperature is kept constant and most of the laws taught in elementary physics tacitly imply constant temperature. This remark is fundamental and I shall give three illustrations.

* Based on a lecture given to the Institute's Education Group at the Institute's House on April 14, 1955.

(1) Hooke's law. The ratio of the extension to the tension of a string (or a spring) is constant at constant temperature, but will usually vary with the temperature ;

(2) Ohm's law. The ratio, called resistance, of the potential difference across a resistor to the current flowing through it is constant at constant temperature but will usually vary with the temperature. Hence, the use of a platinum resistance thermometer to measure temperature ;

(3) Capacity of a condenser. The ratio, called capacity, of the charge of a condenser to its potential is constant at constant temperature, but will usually vary with the temperature.

In the early stages of teaching elementary physics the importance of the condition of constant temperature is passed over without mention. As a consequence, what Sir Charles Darwin has aptly called the dual aspect of energy is obscured. This dual aspect may be resolved into the potential aspect and the conservative aspect, which can be expressed as follows.

Potential aspect : the gain in energy of a system is equal to the work done on the system.

Conservative aspect : the gain in energy of a system is equal to the loss in energy of its surroundings.

If the properties and behaviour of the system were, as tacitly and inaccurately implied in elementary physics, independent of temperature these two statements would mean the same thing. But as soon as we recognize that the temperature does matter and we introduce the simplest possible condition, namely that of constant temperature, we see that the word energy has been used with two different meanings in the two statements. They are in fact two distinct quantities called free energy and total energy respectively. (They are bad names, but I cannot help that.) The corrected statements are as follows.

Potential aspect : the gain in free energy F of a system maintained at constant temperature is equal to the work w done on the system.

Conservative aspect : the gain in total energy U of a system maintained at constant temperature is equal to the loss in energy of its surroundings.

Both free energy F and total energy U may be regarded as functions of a quantity x, which may be the length of a spring or the volume of a fluid or the charge of a condenser or any other such non-thermal variable, and of the temperature T. The increase in free energy F is related to the work w done on the system by

$$w = \frac{\partial F}{\partial x}\,dx = dF - \frac{\partial F}{\partial T}\,dT \qquad (1)$$

and this relation is valid, whether or not the temperature is kept constant. The conservative property of the total energy U is expressed

by

$$w + q = dU \tag{2}$$

where q denotes the heat flowing into the system. It is legitimate to regard (2) as the formal definition of q.

At this stage we are faced with the fundamental question how are F and U interrelated. Any relation between them must involve the temperature and the form of such relation will depend on the chosen scale of temperature. There is a scale of temperature, called the thermodynamic scale or absolute scale, on which the relation takes the strikingly simple form

$$U = F - T\frac{\partial F}{\partial T} \tag{3}$$

Formula (3), apart from defining the thermodynamic scale, is introduced as a fundamental law justified either empirically, i.e. by the fact that all deductions from it are in agreement with observation, or by derivation from statistical mechanics. I myself believe that an elementary form of statistical mechanics can usefullly be taught* before classical thermodynamics, but I am perhaps in a minority. However that may be, there is no harm in taking formula (3) as an axiom, like the laws of mechanics.

From formulae (1), (2) and (3) we derive

$$q = dU - dF + \frac{\partial F}{\partial T}\partial T = Td\left(-\frac{\partial F}{\partial T}\right) \tag{4}$$

and we recognize the quantity $-\partial F/\partial T$ as the entropy, but there is no need to introduce the name at this early stage.

This concludes my outline of the fundamentals of thermodynamics for quasi-static changes in systems tacitly assumed to be in internal equilibrium at all stages. These fundamental relations should be applied to as wide a variety of problems as possible before touching the very different and much more difficult field of irreversible changes. When the time is ripe for this, maybe several years later for physicists and chemists, maybe necessarily sooner for engineers, a completely new start should be made. In this second course of thermodynamics entropy should be introduced together with thermodynamic temperature as early as possible. This is done in my book "Thermodynamics." There would be no point in quoting from it here and I have nothing to add.

I hope that in this brief outline on fundamentals I have not stretched the meaning of the word beyond its breaking point.

* Anyone interested in this method of approach will find it described in a booklet "Boltzmann's Distribution Law" to be published this summer by the North Holland Publishing Company.

THE HISTORY AND PHILOSOPHY OF SCIENCE IN AN UNDERGRADUATE PHYSICS COURSE*

By N. R. HANSON, M.A.
(*University of Cambridge*)

For five years a new subject has been taught within the Natural Sciences Tripos at Cambridge University. I have been associated with the development of this course, and I should like to tell you something of our objectives, and of the difficulties we have experienced. This is the best way for me to contribute to the subject of this afternoon's discussion.

Before I even pose the question of whether or not there is anything to be gained from stressing historical and philosophical factors in the teaching of science, I had better say something about the notions of history and philosophy themselves. This preliminary is important. A remarkable amount of indifference, even opposition, to this new approach to science teaching derives from misconceptions as to just what historians and philosophers find interesting in science. My first task then will be somewhat negative in character ; I wish to make it clear what we at Cambridge do *not* do.

Historians of science are more than chroniclers. Singer, Sarton, Thorndike, Nicholson, Butterfield and my colleague A. R. Hall are not concerned just to construct a master record of what happened and when —of discoveries, inventions, and scientific personalities, of birthdays, and family connexions. True, many books on the history of some science read as if the author were designing a kind of periodic table, or calendar, or genealogical tree, of the events which have made the science what it is. But this is to history of science at its best as bird watching is to genetic theory.

History of science is concerned with ideas—with the thinking of scientists. And this is also what the philosopher of science is interested in, only in a different way.

A consistent opposition to the study of history and philosophy of science ought to begin by denying that scientific research requires any thought at all. For once it is admitted that doing science does require thinking, it is clear that two related studies are immediately important to an appreciation of that thinking. Thinking evolves, and it has an internal structure. The historian explores the evolution of scientific thinking and ideas. The philosopher explores the internal structure of scientific thinking and ideas. This is only generalized from what obtains when any scientist is said to have an adequate grasp of a certain idea. Would we ever say this of a man who lacked

* A lecture given to the Institute's Education Group at the Institute's House on April 15, 1955.

all knowledge of the development of an idea and all knowledge of its internal structure—its logic ?

So the historian of science is not a Royal Society book-keeper, kept to settle future claims as to the priority of inventions and discoveries. He is an explorer. He seeks those factors in the intellectual environment of a given period which led to the formation of a certain pattern of thought. He wishes to disclose new dimensions in concepts such as *acceleration*, *force*, *mass*, *charge*, *field*, *point*, . . ., etc. He does this by revealing factors which inclined men of different scientific periods to fashion these concepts one way rather than another, this way rather than that. Just as we can understand a man's action better when we know something of him—how he has behaved on similar occasions, and why, what his views are on the matter which led to his action, etc.—so we shall have a better grasp of a scientific concept, e.g., H_2SO_4, when we know something of what led chemists to express themselves in this way with respect to this substance.

It has been remarked that the formula H_2SO_4 contains the history of mankind. That may be an exaggeration. But it must be clear that insofar as science masters and university lecturers expose this formula to their students as if it were but a token in an intricate juggling act called " chemical theory," they are losing an opportunity to put a broader, more exciting interest into their presentation of the subject. What is more important, they are failing to disclose the full significance of the formula H_2SO_4 within the system of chemical theory itself.

Notwithstanding an indifference on the part of some scientists to history of science as a discipline fit for undergraduate consumption, few would deny that the sciences have a history. Philosophy of science, however, does not always escape with even this minimal claim. Since I am a practitioner of this black art, I had better proceed to do in detail for philosophy of science what I have done cursorily for history of science. As before, I will begin by saying what philosophy of science is not, or what it need not be.

If history of science is not chronicle, philosophy of science is not a secular religion for conscience-stricken researchers. In this decade the question " Whither science ? " has been posed *ad nauseum*. Divines, demagogues, and despondent dramatists have viewed science as the instrument of gleeful Frankensteins bent on creating the uncontrollable. And so they are led to " philosophize " about the future of our civilization. Doubtless, in an age of bigger and better bombs such questions are worth discussing—they are even worth discussing carefully, a thing which is rarely done. But no matter how well this is done, it is not an issue of internal importance to the teaching of science.

It is a different subject. It affects scientists no more than it affects other members of the community. It is a matter affecting the scientist as citizen, not the scientist as scientist.

If there is a real case for the introduction of history and philosophy of science into undergraduate physics courses, this must consist in the possibility that men may become better physicists as a result. It is this stronger claim that I should like to consider. In any case, the speculative, deep-purple variety of discussion to which I have been alluding finds no place in history and philosophy of science as it is dealt with at Cambridge.

Philosophy of science cannot, of course, increase manual dexterity. It is not unrelated, however, to the business of sharpening one's wits—the business, that is, of considering the character of one's experimental problems, the logical structure of arguments and proofs, and the general nature of a science's subject matter. The details of this I hope to set out in a moment. But I must first allude to another thing that Philosophy of Science is not, or need not be. For scientists often recoil at the sound " Philosophy of Science " for yet another reason.

Physicists rightly dislike the idea of academic philosophers and historians telling them, and the world, what science is all about. If physics were beset with all the problems that professional philosophers and historians manage to find in it, then doubtless they would be handy chaps to have around every laboratory, and every school and university concerned with the teaching of science. But here the scientist will ask : " How can scholars who are unlikely ever to have seen the insides of a modern physics laboratory—who have never muddled and groped through the perplexities of a research task of their own, or felt that profound unsettlement which attends every decision at the frontiers of physical inquiry—how can these individuals be relied upon to know what are the conceptual problems of physics ? " Well, they cannot be relied upon—not unless they have been themselves scientists. Indeed this is an indispensable requirement of anyone concerned with the teaching of these subjects. Unfortunately it is not met by many individuals who expound on the history and philosophy of science.

The physicist's revealing question gains force when one sees how unrecognizable to researchers are some of the problems which " pure " philosophers have about the natural sciences. E.g., How can one " construct " concepts of electrons out of visual impressions of pointer readings ? How can one justify the use of inductive procedures in natural science ? How can one, in the reports of his research, most closely approximate to the manner of exposition of the pure mathematician or the formal logician ?

That these questions are not always recognizable to scientists does not entail that they are unworthy of being asked. Philosophers do ask them and they discuss suggestive answers to them, often with great clarity and insight. But perhaps these problems are not recognized by scientists because they are not problems that scientists *have*, however much they might have had them had they but taken a degree in philosophy. Professional philosophers often refuse to discuss the problems physicists say they have, sometimes with the uncharitable aside that these are too naïve for discussion. This is strange. For who should know better than the physicist himself what conceptual perplexities actually beset his laboratory work ?

A connected consideration is the scientist's uneasy feeling that members of Arts faculties see it as their mission to educate and humanize their underprivileged brethren, the physics researcher and the physics teacher. The vaunted gap between science and the rest of the academic community is to be closed, apparently, by plastering the Cavendish with culture, by threading modern poetry into the study of metallurgy and petrology, by hiding the intellectual nakedness of science graduates with a sheepskin fashioned as much by the dramatic arts as by laboratory science. Doubtless some of this would be a good thing, for there is such a gap. But it is a truth of geometry that gaps can be closed in three ways ; by moving one extreme nearer to the other, or by moving the other closer to the one, or by moving both extremes simultaneously towards each other. It is a presumption on the part of Arts people to complain of the low level of culture amongst the scientific fraternity when so few of the *literati* have even a rudimentary knowledge of the kind of thinking that has virtually shaped the modern Western mind. The assumptions, methods, and attitudes characteristic of natural science since Galileo have had the most profound influence on our contemporary intellectual life. Without some understanding of these, an adequate assessment of the broad pattern of the life and society of our times is impossible. In this respect the physics student who has not read Homer is in a better position than the Classics student who has not read Newton, or who knows nothing of mechanics. It is this feature of the work and thought of physicists which ought to be stressed from within the teaching of physics, at school and at university. Attention to the history and philosophy of science can be a powerful asset in this programme. The rest of this paper will be devoted to making this more clear. For I have said much about what History and Philosophy of science is not ; now I must say what it is, and what it can be used to do.

Are we all agreed that physicists are not just Tripos-tested laboratory machines ? They have to think. But thinking always has a history

and it always has a structure. To understand the history and the logic of an idea is to have a better grasp of that idea. It is to know what shaped the idea as it is. It is to see what are the implications of the idea, what observations are relevant and important to it, and what courses of action with respect to the idea are likely to be fruitful, as well as futile. Consider this further.

Try this question on your students : What is meant when it is said of some theorem of geometry, e.g., that the internal angles of a plane triangle equal a straight angle—what is meant by saying that this theorem is *true* ? Historically, with the advent of the non-Euclidean geometries, this question was seen to be significant. Even casual reflexion on the existence of alternative geometries will scare up the ancillary question : What is meant by saying of the actual space in which we live, the space in this room, that it is Euclidean ? The question seemed natural for the founders of non-Euclidean geometries well over one hundred years ago. But your students are unlikely ever to have heard of the question. Indeed, the majority of university graduates in mathematics or physics have never heard of it. If you put the question to these graduates they will rarely understand its meaning without a thorough interpretation. This is startling when one considers that the question is of central and profound significance in any attempt to understand just what geometry is the study *of*, and just what mathematics is and what physics is.

Inspect any current textbook on geometry. See if you can find half a page devoted to the sense in which geometry is true. If you find anything at all it is likely to be an embarrassed attempt to dodge the question. This is criminal, for it is one of the most fruitful problems that could be put pertinent to the relation of physics and mathematics to other fields and methods of acquiring knowledge. Rarely is the student shown even so simple a thing as that mathematics is a formal science. It can make no pronouncement on matters of physical fact. It deals only with hypothetical statements of the form : *if* proposition A is true then it follows that proposition B is also true. Mathematics *per se* is never in a position to assert that the proposition A *is* true, in the sense in which we can say that the refractive index of diamond is 2·417 (for the λ of the sodium D line). The statements of mathematics are of the form " all bachelors are unmarried." To deny such a statement is not false, it is absurd, meaningless. To deny a statement like " all bachelors are less than twenty feet in height "—that denial would be false. But no such statements can occur in a formal science like mathematics or logic. For mathematics and logic are not concerned with what is, but with what follows.

This failure on the part of science teachers to explore even the surface of the foundations of geometry has an effect on the students

which is, to put it mildly, devastating. For anyone who fails to grasp the relationship between mathematics and physics at this simple level is certain to fail to grasp the relation between experimental confirmation and mathematical proof in more intricate domains of advanced physics. He is bound to misunderstand the role played by mathematical theory in quantum physics, in field theory, and in theoretical chemistry. A well known university text book asserts that Einstein proved " mathematically " that a material body cannot move with the speed of light. The most charitable thing one can say here is that the author has not expressed himself felicitously. But my suspicion is that he is unaware of the remark made by Einstein himself, namely, that in so far as mathematics applies to reality it is not certain, and that in so far as mathematics is certain it does not apply to reality. How then could it be proved by mathematics that no body can exceed the speed of light ? Most students of physics are not even given an instinctive feeling that no statements of physics can be proved mathematically, but that every so-called proof in natural science consists only in deriving (by mathematical means) one statement of physical fact from other statements of physical fact. When one surveys some of the recent history of quantum theory it is impossible to avoid the conclusion that this instinct is not as strong amongst our bright young researchers to-day as it was for Einstein, Rutherford, Bohr, Dirac, Schroedinger, Heisenberg, and Born, men who have enriched philosophy of science by their acute analyses of which were the logical and which the experimental factors operating in their most important work.

The traditional " engineer's manual " approach to the teaching of physics has missed this opportunity to make clear to the student a distinction which is central both to the full understanding of his own science, and to many problems of interest in our society. In any field which could profit from a reasonable, scientific approach a central consideration must be the relationship between one's data—or evidence, or facts—and the conclusions which justifiably may be drawn from those data or facts. In a terse small-scale form we have here, in the distinction between pure geometry and the physics of actual space, a special case of a general issue concerning the interaction between experience and reasoning, between practice and theory.

Why have we so long ignored this chance to add a new dimension to our physics teaching ? Why have we been inclined to regard these considerations as something extrinsic to the actual business of teaching physics, to the business of getting the little blighters to trot out the correct formula at the correct time ? It can only be that we have not ourselves been alert to the full meaning of the formulae. H_2SO_4 may not contain the whole history of mankind. But if it is carefully laid

before the student he can come to feel what must have been the impact of this notation on chemical thinking in the 19th century, he can come to detect the important affinities, between operating and calculating with this set of symbols and operating and calculating with other symbols in other sciences. Indeed he can even come to form an idea of what a computational device can do in a natural science.

Why should he be denied this? If he is any good he will have to learn it for himself later. Even if he should drop out of science it cannot but have benefited him to have seen how experience and thought as they relate in physics is only a special case of the relation of experience and reason in every field of human endeavour. Certainly the failure to grasp this relationship accounts for some of the confusion felt by those perplexed with the complexities confronting them in private and in public life.

Thus the respective roles of mathematics and physics in our understanding of geometry is the simplest, most forceful example from the consideration of which the student can discern something of importance to his understanding of science in particular, and of problem-solving in general. In fact every problem in physics gives us such an example. Another is provided by Newton's laws of motion.

The first and second laws look very simple. Actually they are crucial issues for every teacher of physics. Their superficial simplicity makes any confusion in their presentation stand out in bold relief. A similar confusion in an advanced subject, like the three body problem, passes unnoticed. But it is no exaggeration to say that 90 per cent of the textbooks available for the first two years of university physics present the law of inertia so that its meaning is obscure. The words used in its formulation are applicable to no actual situation in the physical world. "An isolated body moving free of impressed forces is moving along a straight line." These words are jammed full of exciting questions discussion of which is essential to any real understanding of the law. These are usually suppressed in favour of getting on with the symbolic Meccano. And the student receives a further encouragement to regard mechanics as a dead catalogue of formulae rather than as what it was for Galileo, Newton, Hooke and Laplace, the most thrilling and spectacular of intellectual achievements.

What is an isolated body? Do we have any concept at all, much less a clear concept, of a body moving free of impressed forces? Aristotle, whose genius no one would question, took a different view of the matter. So its truth cannot be self-evident or obvious. For Aristotle, undisturbed bodies in motion always came to rest. This is not bad physics. Observation and experiment are largely in support of Aristotle. If one of your bright students were to adopt the Aristotelean position here, how would you bring him around?

What would you point to, what could you show him? Indeed just what are the considerations which compel our assent to the first law? Once posed, the question opens the whole fascinating business of theory-construction before us.

What a revelation it can be to a student to learn that we accept the law of inertia for just the sorts of reasons that we accept atoms, and electrons which spin and move in a manner formally analogous to the movement of a wave group, and neutrons, and positrons and neutrinos. We cannot just look and see any of these things directly. But the student will learn that this does not matter. By assuming these things—the law of inertia, electrons, neutrinos—many of the things we do observe directly can be clearly and powerfully explained. What better reason could there be for assuming them? Not one schoolboy or undergraduate need persist in regarding mechanics as a text of dry lessons which must be mastered before he can get on to "the exciting stuff." For classical mechanics is physics. It involves decisions of great importance for every concept built upon it. It is riddled with ideas and unanswered questions of exactly the same type that punctuates contemporary physics. The earlier the student comes to feel the fundamental, philosophical character of the concepts with which he must deal, the better able will he be to make his own decisions and form his own views when he stands at the frontiers of a problem where there are no hackneyed textbooks to guide him or misguide him.

Let the student know that Mach regarded the first law as an unnecessary tautology completely contained in the meaning of the second—and let the student discuss this. Let him know that for Mach the empirical content of the second law lies in our ordinary experience of forces and tensions in our muscles. For Hertz, on the other hand, the second law is only an implicit definition of the terms concerned; let the student discuss this, after reminding him that Maxwell himself first speaks of the laws as pure definitions and then proceeds to list the experimental evidence in their favour. This is rather like asking the mother of a newly-born child what evidence she has for calling him "James."

Soon the student will come to see that though these matters are the conceptual glue which holds all of physics together, there are here no neat, tidy answers—not in the sense that there are answers to the specific questions which this glue makes it possible to ask. Nothing can match such discussions for destroying the schoolboy conviction that physics is a great shelf of thicker, more unreadable textbooks and directories, all containing the right answers in the back pages. If science were just such a shelf then there would indeed be an unbridgeable gap

between it and other discliplines. No student with initiative or imagination would dream of undertaking such a study.

Consider the first law further. It is usually presented in the language I used a moment ago. But clearly, " moving along a straight line " is an expression without physical meaning unless some reference system is physically specified, a system in which a straight line is defined and fixed so that it can serve as the standard by which we judge whether a given motion is rectilinear. In current textbooks one rarely finds even the perfunctory statement that the system of reference needed in the first law is the system of the (so-called) fixed stars. Thus the law as stated in the textbooks lacks even a vague meaning since no method is described or even suggested whereby it can be considered in a concrete case.

So long as the nature of the verification of a physical law remains obscure, the way is clear for every opinion as to its character and validity. In some books the law of inertia is taken to be self-evident and Aristotle's dictum to the contrary is ridiculed. Others regard the law as not at all self-evident ; they say that it is confirmed in familiar experiences, such as that a chair will rest immobile on the floor unless we lift it or push it. Still other books construe the law as a theoretical hypothesis, no more, no less. It cannot be proved by any experiment, but it is not for that reason self-evident. The law of inertia is really all these things. It can be used in a variety of ways in different contexts. If a physicist thinks he is checking the first two laws by the use of Atwood's Machine then he is clearly using the laws differently than when he employs them as inference *schema* in celestial mechanics, or when he uses them in calculations concerned with the construction of apparatus. Most books try to settle the issue once for all. This is rather like trying to settle once for all what is the use of a rope, or a plank of wood. Laws of motion, like planks and ropes have as many uses as there are contexts in which they can be used. Of all people the writers of physics textbooks should know this.

Of course the issue here is nothing less than the character of man's knowledge of nature, an issue which the science student ought to be better able to understand and discuss than the Arts student. But it is just this understanding and discussion which is suppressed in the standard, stern, omniscient presentation of the subject. The result is that science teaching loses another opportunity to reveal the full importance of physical thinking. The " gap " of which educators never tire of talking remains, whilst well-meaning Arts teachers try to sandwich thin slices of Shakespeare between thick crusts of statics and Snell. Physics teaching does not need this superficial humanizing from the outside. It ought to be an inside job. For physics is itself the most human of accomplishments ; man's relentless struggle to form a

systematic set of conceptions about the world in which we live. Were this potentiality of physics teaching realized it would soon be obvious that the serious gap lies in the ignorance of Arts students to the elements and principles of that science which has to a remarkable degree determined what to-day's men of letters think about.

Search in a physics text for an evaluation of the law of inertia. What do you find ? " It is amazing that it took so many centuries to discover such a simple and trivial law." If it was so simple and trivial why did it take a Galileo and a Newton, nothing less, to offset the views of Aristotle (who was at least as capable as these modern text book writers of discerning the simple and the trivial). By simplifying and trivializing these laws we lose yet another opportunity to disclose the achievements of early physicists. And we are in danger of promulgating the parochial idea that only the research of our own day is difficult, exciting and intellectually challenging. All the work of earlier days was simple and trivial.

Think yourself into Galileo's context. Try to come to appreciate the effort it must have required even to form the theoretical concept of acceleration. That effort was at least as great as that required of Planck, Einstein, Compton and De Broglie in their individual achievements of 1900, 1905, 1923, and 1924 respectively. How wrong we are to let it sound as if these latter were discoveries requiring some different kind of intellectual effort than did the laws of acceleration and inertia. When a teacher calls fundamental laws of classical mechanics " simple and self-evident " he has not himself understood their real significance, either for physics or for human history. He has not given his students a correct presentation.

If elementary texts formulate the first law in elaborate but meaningless ways, advanced texts seem proud to minimize it altogether. In one such book the law is called " self-explanatory." This saves the author from having to explain it, since the law is busy explaining itself. He then treats the law as a special case of the second law, as do most writers : if F is 0 then a is 0 too, and the body moves with a constant velocity. The difference between this and what is said in the elementary books is that here it is not the first but the second law which is formulated in an obscure way.

Ask any graduate student what " acceleration " in this law means. He will say that the acceleration is the second derivative of the co-ordinates with respect to time. Then ask what he means by " co-ordinates." He will make the usual reference to a Cartesian co-ordinate system. But a motion of a body is described physically only if we can specify its co-ordinates with respect to a system consisting of physical bodies which are observable. An operationally sound account of what is meant by " acceleration " in the second law must

describe a physical Cartesian system. This cannot be in fixed connexion with our earth. The fixed stars may serve as a first approximation. If that is so then acceleration is (approximately) " with respect to the fixed stars of our galaxy." Even Ph.D. candidates often show little awareness that the unqualified expression " fixed in space " may be meaningless in physics. Persistent questioning will soon reveal to them that they have not thought nearly enough about the " simplest " laws of their science.

Failure to describe the physical system of reference makes little difference to the engineering student. No bridges of his design will collapse because he never heard of the difficulties involved in the concept of acceleration. Were this innocence preserved in physics, however, it would soon be obnoxious. The fixed stars do not form a rigid Cartesian system. So they cannot replace the abstract, purely formal term " Cartesian system." Here is a situation analogous to that mentioned earlier concerning the applications of pure geometries to actual spaces. Whether there is a physical space which can be described by Euclid's geometry is a matter for experiment, observation and inquiry to decide. It is logically possible that we might be wrong in saying of any actual space, e.g. the space in this room, that it is Euclidean in every respect. Similarly, whether there is in the universe a physical Cartesian system with reference to which the laws of Newton's *Principia* can be observed to hold is also a matter for experiment, observation and inquiry to decide. Again, it is a distinct possibility that we might be wrong in saying of any actual portion of the universe—e.g. the matter enclosed by the orbit of Pluto—that its behaviour is Newtonian in every respect. So we must say that the positions and velocities of the fixed stars, and even of the remote nebulae, determine in some way the system of reference intended when the term " acceleration " is used without further specification. Thus our rolling billiard ball is physically influenced by the states of the stellar bodies constituting our Milky Way. These, and the galaxies millions of light years distant, determine the motion that we call " motion under no force."

Here is a startling and exciting fact about the world. One can only learn it through physics. This makes the suppression of the fact by textbooks and teachers difficult to understand. By ignoring the influence of the large but remote masses of the universe, the mysterious concept of absolute space was smuggled into physics, to the consternation of everyone who had later to fight off its influence. Yet we are at no great pains to-day to insure that the concept never gets a grip on the student. Perhaps later the effort required of him to fight off this idea will be good for his soul. That may be true. But as a pedagogical technique it is of at least debatable value.

Foundations of geometry and the laws of motion : these are just two of a large number of crucial concepts in physics the free discussion of which can deepen the student's understanding of the kind of knowledge science can give him, and of the fundamental ideas which hold physics together. This is not something to be tacked on to physics. It is not a sugar-coated afterthought, something to disguise the hard work that must be mastered one way or another. It will grow up from within the actual teaching of physics if it is allowed to do so.

Before concluding I should like to mention how Dr. Hall and I proceed with the undergraduates at Cambridge.

It has been essential that we have a pretty good idea of what the undergraduates are doing from week to week in their science lectures and laboratories. When I first went to Cambridge from " the other place " I devoted most of my mornings to attending the physics lectures with my students. My own lectures were designed accordingly. When Professor Sir Lawrence Bragg was lecturing on Optics, he dwelt in detail with interference phenomena, and he raised interesting general questions about the controversy as to the nature of light. At just this time Dr. Hall was considering what inclined Newton towards holding a corpuscular theory. He was dealing also with Huyghen's recommendations in favour of the undulatory theory. Hall is always careful to stress the essential opposition in *ideas*—the intellectual content of such disputes. Student's reactions showed that this historical excursus complemented Sir Lawrence's lectures admirably.

Then Hall moved straightaway into a treatment of the conceptual context in which Young, Fresnel, and ultimately Foucault, conducted their famous experiments. At this point I had been lecturing for about a week on the general question of crucial experiments in physics —what they are, whether they are desirable and when they are possible. So it was natural to consider these experiments further, for they are all described as " crucial." If they were crucial we should never again have heard of the corpuscular theory of light. This has spectacularly proved not to be the case. Exploring further, we found that these 19th century experiments were indeed crucial, but only against an implicit background of assumptions like this : Young, Fresnel, and Foucault all accepted the prior proposition, " Light must propagate itself in either (1) a wavelike manner, or (2) in a particulate manner, but (3) in at least one of these ways, and (4) in no case both of these ways at the same time." There was no justification for holding to (3) and (4), though as Hall shows it was then natural to do so. Yet it is equally clear that these experiments could be regarded as crucial to deciding the nature of light only if the logical condition expressed in the clause " . . . but in at least one of these ways and in no case both of these ways at the same time," were accepted

without question. The discoveries of this century have shown not that light is not really undulatory after all, but that Young, Fresnel and Foucault were perhaps too hasty in their acceptance of what is expressed in this important but seldom noticed clause.

So it is with all so-called crucial experiments. They are crucial only against a background of theory and presupposition which must be beyond dispute so long as the experiment is still regarded as crucial. Question these presuppositions and the forbidden apple is bitten. It becomes immediately clear that the finality of the word " crucial " is bought by mortgaging away all expectations that anything new may yet be discovered which will change our ideas as to the character of the phenomena before us.

These historical and philosophical discussions provided a rich context for Sir Lawrence's lectures. It was clear that everyone concerned profited from this liaison. Hall and I resolved to let the science lectures provide the texts on which we would preach.

Similarly, Mr. J. A. Ratcliffe lectured in Part I Mechanics last year using Ernst Mach's book *The Science of Mechanics*. As you know, Mach is a gold mine of historical and philosophical nuggets. We lost no time in meshing our work with Ratcliffe's lectures. Hall was then discussing Galileo and Newton and the great advances they brought to mechanical thinking. I was examining the logical structure of a physical theory like the Mechanics of Newton or of Hertz ; I explored also the logical nature of the Principles, Laws, Generalizations and Hypotheses which must figure in any such theoretical system.

Threading our questions into the actual day to day teaching of the straight physics lectures has been effective. Enthusiasm has sprung up at Cambridge, amongst dons and undergraduates alike. Our Philosophy of Science Club this year recorded 250 members, of which number some 50 were of senior standing in the university. Plans to advance and intensify work in the history and philosophy of science within the Natural Sciences are now at an advanced stage at Cambridge, with the support of almost all of the major scientific faculties.

It is too early to say what will be the long term effect of this deepening of science teaching—notice that I say " deepening " rather than " broadening." The broadening will come naturally when the fundamental aspects of physics are exposed and discussed in schools and universities. For of all man's efforts to make his surroundings intelligible nothing can approach physical inquiry as an exciting, formally beautiful and intellectually challenging exploration. Anything that can bring these aspects of physics into better focus is worthwhile. More attention paid to the historical and philosophical aspects of physics might serve as a lens for the achievement of this better focus.

THE EDUCATION OF PHYSICISTS IN TECHNICAL COLLEGES

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A few years ago The Institute of Physics published a pamphlet, with the title *The Scientific Education of Physicists*, which commented on some aspects of the education and training of physicists, and listed information concerning the facilities available in the Universities and some of the Technical Colleges of this country.

Traditionally physicists have been trained in the Universities, and until quite recently such a training provided the one road into the profession. Some physicists, however, came up the hard way through the Technical Colleges and obtained a degree qualification after years of attendance at evening classes. (Birkbeck College, London, is unique in being a University College which exclusively provides such evening instruction).

The University courses follow a fairly common plan of lectures and laboratory work, extending usually over three years, but there is naturally some difference of emphasis and of content from University to University. With the vast developments in the subject the content of courses has inevitably had to be reshaped and is likely to change even more. Further, the increasing responsibilities of physicists in industry and Government service, as well as other social factors, have caused University teachers and others to think more fundamentally of the education aims which should serve as a guide in framing any course for physicists. Interesting changes have been made.

In Technical Colleges, until comparatively recently, what courses there have been for physicists have followed the University model—in so far as accommodation and equipment allowed. For many years now some of the larger Colleges have provided courses leading to the degree of B.Sc. General or B.Sc. Special Physics of the University of London. Before 1939 these were mainly evening courses but a few Colleges had a small number of full-time students. From 1945 onwards, mainly owing to the Universities not being able to accommodate the large numbers of ex-service men, the full-time degree courses in Technical Colleges developed considerably and more and more Colleges took up such work. However, it was always apparent that the demand for these degree courses was temporary and would fall steeply, as it has done since 1952 ; the majority of Colleges undertaking work of this type now have only a few students and the full-time degree courses, and possibly the evening courses, are likely to disappear. It will be readily recognized, however, that at a time of national need

the Technical Colleges did a real service ; they trained many who now occupy important industrial posts.

But several searching questions assail us : Have the Technical Colleges really been diverted too much from the work for which they are specially fitted ? Should they, particularly in these post-war years, have been trying out a different type of training, producing a different sort of physicist of which industry is in need ? And what should they do now ?

In 1943 the Board of the Institute approved and published a report in which it recommended that it should not be a primary function of a Technical College to educate students for external University degrees, and further, that some other recognized professional qualification in physics should be available. The Percy Committee, which published its Report in 1945, was divided about the nature of the qualification to be conferred by the new Colleges of Technology which were to be established, but it did attempt to clarify the difference of functions of these Colleges and the Universities. It emphasized the need of industry for a type of entrant, different from the technologist coming from a University Department or from a Technical College Diploma course ; it therefore suggested a course of training broader than the latter but of University degree standard and planned on different lines.

And through the intervening ten years, the discussion has proceeded, more and more Committees have been set up, more and more reports have been published, and many have awaited, for too long, a statement of national policy. It has become increasingly clear to many Technical College teachers that the remedy lies in their own hands ; they must put their own house in order ; they must inaugurate new courses and new methods of training which their experience and knowledge of industrial needs specially qualify them to undertake. For too long have they waited, for too long have they been tied to the external University degree, for too long have they hoped for a new status. But status, as one of the Institute's reports wisely say, " will depend on the extent to which the Colleges fulfil what is regarded as their essential function and will not be acquired by comparatively minor changes of organization or of the nomenclature of awards."

In recent months a few Technical Colleges have quite independently put forward new schemes of training for physicists, but suitable for adaptation for technologists generally. They are firmly based on Technical College experience and therefore old in concept, but yet they may " mark a new era in technical education." These Colleges propose to introduce sandwich schemes of education, allowing for six months' College training followed by six months in industry, over a period of four years. Entry will normally be at about 18 years of age,

for those who have passed appropriate subjects in the General Certificate of Education Examination at the Advanced Level, or have passed at a sufficiently high standard an Ordinary National Certificate Examination. Most of the students will already be in industry, so that each scheme is "industry-based," but it can equally well be "College-based" and admit students straight from School. Some firms have already indicated that they would accept such "College-based" students for their periods of six months' industrial training.

Physics and mathematics will be included in each year of the course to the standard of a first degree, but at all stages the applied aspects of the subjects will be dealt with, and special options in applied physics will be offered in the final year of the course. The facilities Technical Colleges have for teaching such subjects as workshop practice, glass-work, engineering drawing and properties of materials, will be used to the full. Some branches of modern physics will be included but one special aim will be a good understanding of classical physics. Another emphasis will be on the laboratory work, on training in experimental methods and the assessment of accuracy. The mathematics will be treated in the spirit of the Institute's report on the teaching of the subject; there will be an emphasis on numerical and approximate methods, and statistics and the use of statistical techniques will be taught throughout.

Obviously as the Colleges will have freedom in designing their courses, in selecting the syllabuses and in setting the examinations, subject to the approval of External Examiners, appointed by them, they have a great opportunity. Relieved of the frustration of working for external examinations, and guided by their experience of teaching students preparing for the National Certificates in Applied Physics, they will be in a position to make a new and valuable contribution to education practice.

A great feature of any new venture is that we are stimulated to attempt to answer the question: "What are we trying to do?" Incidentally we thus avoid getting lost in the details of the scheme. We do well to remind ourselves, that if one of our aims is to help the students to acquire a knowledge of physics and of the applications of physics in industry, there are still more important ends we should have in view. We should also help the students to appreciate the scientific approach to a problem, how a physicist tackles the new and unknown, and how he expresses a scientific answer to a question. This is difficult to achieve; it cannot be enshrined in a syllabus but it must permeate all our teaching. Further we must remember the greater world outside physics in which we live, and all the problems of relationships involved. These are challenges to the best of teachers.

The award granted to successful students at the end of such courses as are envisaged has often been regarded as all important, and has inhibited change. But important as it is, some of us have come to take a different point of view, assured that what is paramount is that industry (and the world generally) should find the products of this new mode of training acceptable, and that the Institute should give them professional recognition. The Colleges will probably award a. Diploma (a misleading term) or Associateship. But whatever the name, it is reassuring to know that the Institute of Physics which has for so long advocated changes in line with those proposed will give full recognition to these new awards.

REVIEWS OF BOOKS

Intermediate Heat. By PHILIP PARKER, M.Sc., F.Inst.P., A.M.I.E.E. (London : William Heinemann). Pp. 216. Price 11s. 6d.

The conflict between a logical sequence of ideas from the reader's point of view and a presentation which the pupil can understand properly at every stage has been happily resolved in this excellent text book. Temperature and heat measurement, and the law of conservation of energy are explained briefly in an introductory chapter ; and the theory of thermometry and pyrometry is treated fully towards the end of the book, when the reader will have reached the stage at which he can hope to master it more easily. Again, the gas laws and the kinetic theory of gases appear early in the book, so that these important topics can be accepted all the more readily by minds not satiated with the arithmetical drudgery of expansion. The author, in short, offers a carefully planned course instead of the mere raw materials to be integrated by the teacher.

The diagrams are good, particularly those drawn to illustrate such difficult points as the barometer correction, real and apparent expansion, and the temperature distributions down good and bad conductors. A number of worked examples appear at the beginning of each set of exercises, and these should encourage a proper style in the setting out of answers.

The standard is about that of the Advanced level of the General Certificate of Education, or Intermediate B.Sc., and the book should prove valuable to students taking physics in these examinations.

G. R. NOAKES.

Laboratory Introduction to Physics. By WALTER G. MARBURGER and CHARLES W. HOFFMAN. (McGraw-Hill Book Company Inc.). Pp. 147. Price 12s.

This is a laboratory manual of class experiments in physics forming a two-year course corresponding approximately to our Ordinary Level G.C.E. in Practical Physics. Each experiment is clearly set out on a single perforated sheet and, after the results have been entered in the columns provided, these sheets may be detached for marking and afterwards filed as a permanent laboratory record. At the end of each experiment are a number of questions to test the reasoning ability of the pupil and these are very searching and wholly admirable.

The emphasis throughout is on technology and the book would be of most use in Junior Technical Schools or in an introduction to practical work in physics in a Services School.

Before it could be used as a class manual in this country some revision of the text would be necessary and some of the instructions in experiments using mains voltages would need to be modified in view of the danger of the higher mains voltage in this country.

The sections on Radio and Photography seem very out of place in a first laboratory manual and could be omitted without affecting the remainder. The use of the cathode ray oscilloscope to verify the relation between frequency, tension and length of a stretched wire is surely unnecessary and such complexity of apparatus would only confuse the beginner. In an otherwise excellent text it is surprising to note that the fallacy of " verifying " Ohm's Law using a current-operated voltmeter still persists.

To the physics teacher in this country this manual has its main interest in the glimpse it gives of elementary physics instruction in the U.S.A.

W. B. CHIVERS.

A Budget of Paradoxes. By AUGUSTUS DE MORGAN. Two volumes bound as one. (New York : Dover Publications Inc.). Pp. xiii + 402 + 387. Price $4.95. With a new introduction by Professor Earnes Nagel.

Augustus De Morgan was one of the great teachers of mathematics of the nineteenth century, occupying the chair of that subject at University College, London, from 1828 to 1866. He resigned in protest when the College Authorities showed discrimination on religious grounds against a candidate for another professorship. He was a man of determination and courage, but another side of his character is abundantly demonstrated in his *Budget of Paradoxes*.

A paradox is defined as " something which is apart from general opinion, either in subject matter, method or conclusion." This " budget " is a salutary reminder of the many byways not usually included in our streamlined textbooks. Living " paradoxers " greatly worried De Morgan. His irritation with their correspondence is rather amusing; he was evidently much more tolerant than he admits.

In this delightful but rambling collection of essays there is no logical sequence, but the quadrature of the circle is a recurrent theme. De Morgan shows great patience in analyzing the fallacies involved in solutions past and present. The book is well edited in that full biographical notes of the many personages mentioned are included. Furthermore, the Latin, Greek and other quotations are fully and accurately translated.

F. H. GAGE.

Science and its Background. By H. D. ANTHONY. (2nd Edition). (London : Macmillan and Company). Pp. x+338. Price 20s.

This book tells the story of scientific discovery from the beginnings of civilization to the present day against a background of history. This object is achieved by grouping most of the material around brief biographies of outstanding scholars and scientists, and convenient Summaries are given periodically in the form of time charts. These consist of three columns under the headings of Action, Knowledge and Vision. Such an ambitious project might well have led to the production of a condensed and rather dull catalogue of events and dates, but by a well-balanced choice of topics chosen from most branches of science, the author has succeeded in producing a most readable and fascinating history of science. It is illustrated by numerous illustrations, aptly chosen and well reproduced.

In this second edition of his book, Dr. Anthony has added two important chapters, one on the utilization of science, in particular since the end of the Second World War, and another on Science for its own sake. In the latter, he illustrates the nature of what he means by the scientific adventure by reference to developments in radio-astronomy, the search for living coelacanths, and the ascent of Mount Everest. It is a pity that the publication was evidently a little too soon to correct the description of the discovery of Piltdown man ! However, the book is one which no one interested in science could fail to enjoy reading.

G. VAN PRAAGH.

Numerical Methods. By A. D. Booth. (London : Butterworths Scientific Publications ; New York : Academic Press Inc.). Pp. 195. Price 35s.

The author of this book states that his aim is to give an understanding of the basic principles on which numerical analysis rests, rather than to give instruction in the details of carrying out a calculation. In the series of lectures and demonstrations by the author, on which the book is based, the actual labour of calculation was done by an automatic digital calculating machine, and the book is meant primarily for those who are concerned with the task of programming for such machines. The original lectures, however, were addressed to mathematics students and it is unfortunate that the author has not modified the style of presentation so as to make it more suitable for those who are using automatic machines but are not professional mathematicians.

As this book comes so soon after Professor Hartree's *Numerical Analysis*, it is inevitable that the two should be compared. In the reviewer's opinion the only advantage of the later book is that it has chapters on integral equations, Fourier synthesis and analysis, and approximating functions, whereas these are missing from Hartree's book. Apart from this, all the usual topics, interpolation, numerical differentiation and integration, summation of series, linear and non-linear algebraic equations, ordinary and partial differential equations, relaxation techniques, etc., are dealt with by both authors but in general Hartree gives a fuller treatment in a book which has 92 pages more but which costs 5s. less.

There are numerous printing errors, omissions and obscurities, and altogether the standard of production is unsatisfactory. For this, author and publisher alike must share responsibility.

J. Crank.

Atomics in the service of mankind. A *Daily Mail* publication. Price 2s. Pp. 64.

This is an interesting and useful exercise in co-operation between journalist and scientist. It is a copiously illustrated 64 page newspaper supplement, although several of the pictures seem wholly irrelevant. The articles are, of course, intended for the general reader and on the whole are probably suitable for that purpose, although parts of them also seem irrelevant.

The following reports have also been received :—

Yorkshire Council for Further Education, 26th Annual Report. Pp. 51. Price 1s. 6d.

Sir John Cass College. Annual Report for 1953-54. Pp. 21.

International Tin Research Council. Annual Report for 1954. Pp. 28.

The British Iron and Steel Research Association. Annual Report for 1954. Pp. 144 + ii.

Joint Establishment for Nuclear Energy Research, 3rd Annual Report. Pp. 28.

The Nuffield Foundation. Report on Grants 1943-53. Pp. 319.

National Research Council of Canada. 1955-56 Postdoctorate Fellowships. Pp. 89 + vii.

Year Book of The Textile Institute. No. 7, 1954-55. Pp. 70 + 178 + xviii. Price 15s. 0d.

The British Electrical and Allied Industries Research Association. 34th Annual Report. Pp. 153.

NEWS OF MEMBERS

Fellows

DR. R. N. BRACEWELL has been appointed Visiting Professor of Radio Astronomy in the University of California, Berkeley.

PROF. G. W. BRINDLEY, lately Reader in X-ray Physics in the University of Leeds, who for two years has been Research Professor of Mineral Sciences in the Pennsylvania State University, has been appointed (as from July 1, 1955) Head of the Department of Ceramic Technology and Professor of Solid State Technology in this University.

DR. H. F. COOK has been appointed Reader in the Department of Physics, The Middlesex Hospital, London.

DR. H. G. HOWELL is now Director of Research and Development of The British Plaster Board (Holdings) Ltd.

PROF. R. W. JAMES has been elected to Fellowship of the Royal Society.

DR. T. R. KAISER has been appointed Lecturer in Physics in the University of Reading.

PROF. A. C. B. LOVELL has been elected to Fellowship of the Royal Society.

M. P. NEWBY is now a physicist at the English Electric Company Ltd.

H. T. RAMSAY has been appointed Director of the Safety in Mines Research Establishment of the Ministry of Fuel and Power.

J. B. REID is now employed by Adalia Limited, Canada.

B. SUGARMAN is now Head of the Physics Section of The British Glass Industry Research Association.

DR. H. TOMPA is now Head of the Theoretical Physics Section of European Research Associates in Belgium.

DR. D. WALKER has been appointed to the Chair of Physics at Victoria University College, University of New Zealand.

Associates

MRS. M. H. H. BUNTON has been appointed a Senior Lecturer at Homerton Teachers' Training College, Cambridge.

DR. J. C. BURFOOT is now Lecturer in Physics at Queen Mary College, University of London.

V. G. CATTRELL is now a physicist in the Radiotherapeutic Unit of the Western General Hospital, Edinburgh.

J. COLLINS has been appointed Adviser of Studies in Science and Assistant Secretary of the Appointments Committee in Glasgow University.

DR. E. G. WOODROOFE has been appointed Head of the Research Division of Unilever Ltd.

DR. W. GRATTIDGE is now a Research Associate at the General Electric Company Ltd.

DR. H. C. LEWIS has taken up an appointment as Physics Master at King Edward VI School, Southampton.

T. P. MACRAE is now Research Officer in the Biochemistry Unit of the Wool Textile Research Laboratories, Melbourne.

D. MURRAY has taken up an appointment at the National Physical Laboratory.

D. RAYNOR is now a Senior Scientific Officer in the Royal Naval Scientific Service.

K. SWAMINATHAN has been appointed Assistant Superintendent of Development at the Technical Development Establishment (Instruments) Indian Ordnance Service, Dehra Dun.

H. E. TAYLOR is now Head of the Physical Laboratories with Parkinson and Spencer Ltd., Halifax.

Graduates

DR. R. G. FREEMANTLE is now a Scientific Officer at the Atomic Energy Research Establishment, Harwell.

R. S. KOSKY has changed his surname to Morland.

K. R. MACKENZIE is now employed by Ferranti Ltd., Edinburgh.

M. W. STRINGFELLOW is now employed by the Imperial Chemical Industries Ltd., Dyestuffs Division.

A. TURNER is now a Research Physicist at Ericsson Telephones Ltd., Beeston.

THE REGISTER

ELECTIONS TO MEMBERSHIP

An asterisk (*) indicates transfer from another grade

Fellows

*Bruce, Colin F., M.Sc., Principal Research Officer, Commonwealth Scientific and Industrial Research Organization, National Standards Laboratory, Sydney.

*Buchanan, Thomas J., M.A., Ph.D., Research Assistant, Middlesex Hospital Medical School, London.

*Donovan, Brian, B.Sc., Ph.D., A.R.C.S., D.I.C., Senior Lecturer in Physics, Northern Polytechnic, London.

*Menter, James W., M.A., Ph.D., Research Scientist, Tube Investments Research Laboratories, Hinxton Hall, Essex.

*Oliver, Raymond, M.Sc., Principal Physicist, Oxford United Hospitals, Churchill Hospital, Oxford.

*Woolley, Robert L., M.A., Ph.D., Professor and Head of Physics Department, College of Arts and Science, Baghdad, Iraq.

*Wright, Leonard, M.Sc., Lecturer in Physics, University College of Swansea.

Associates

Antell, George R., B.Sc., Physicist, Research Department, Metropolitan-Vickers Ltd., Manchester.

Armsdon, Stanley R., B.Sc., Engineer, Costain-John Brown Ltd., at present attached to Atomic Energy Research Establishment, Harwell.

Bowness, Colin, B.Sc., Electronic Engineer, Electric and Musical Industries Ltd., Feltham.

Burge, Eric J., B.Sc., Assistant Lecturer in Physics, Norwood Technical College.

*Cartz, Louis, M.Sc., Ph.D., Research Assistant, Cavendish Laboratory, Cambridge.

Davies, Dewi A., B.Sc., Ph.D., Research Assistant, Biophysics Department, Postgraduate Medical School, London.

*Evans, John C., B.Sc., Assistant Lecturer in Physics, Leicester College of Technology.

*Fenton, Frederick C., B.Sc., Second Physics Master, King Edward's Grammar School, Aston, Birmingham.

*Graham, James, M.Sc., Hackett Research Student, University of Birmingham.

Gupta, Ramesh C., M.Sc., Lecturer in Physics, Lucknow University, India.

Harker, Dorothy O. C., B.A., Part-time Lecturer, Wimbledon Technical College.

*Harlow, Reginald G., B.Sc., Ph.D., Research Assistant, Woolwich Polytechnic.

Heslop, Thomas E., B.Sc., Lecturer in Physics, Rutherford College of Technology, Newcastle-on-Tyne.

Holloway, Richard C., M.Sc., Scientific Staff, Medical Research Council.

*Holloway, Robert H., B.Sc., Assistant Lecturer in Physics, North Staffordshire Technical College, Stoke-on-Trent.

*Hope, Stanley, B.Sc., Process Control Engineer, Royal Dutch-Shell Group.

Howells, Glyn, B.Sc., Marconi Instruments Ltd., St. Albans.

Jeffcock, David, B.Sc., Assistant Lecturer in Physics and Mathematics, Wolverhampton and Staffordshire Technical College.

Johnston, James T., B.Sc., Physicist, United Kingdom Atomic Energy Authority, Capenhurst.

*Kahan, David W., M.A., Junior Radar Engineer, Edison Swan Electric Co. Ltd., Middlesex.

Macfie, Daniel, B.Sc., Research Officer, British Cotton Industry Research Association, Shirley Institute, Manchester.

McGregor, Peter M., B.Sc., Geophysicist, Bureau of Mineral Resources, Melbourne.

Nyburg, Stanley C., B.Sc., Ph.D., Assistant Lecturer, Chemistry Department, University College of North Staffordshire.

Payn, David W., M.A., Scientific Officer, Admiralty Compass Observatory, Ditton Park, Slough.

*Ranger, Alan E., B.Sc., Investigator, British Iron and Steel Research Association, Sheffield.

Seymour, Edwin F. W., M.A., D.Phil., Lecturer in Physics, University of Leeds.

Thong, Saw Pak, B.Sc., Ph.D., Lecturer in Physics, University of Malaya.

*Tildsley, Francis C. J., B.Sc., Physicist, United Kingdom Atomic Energy Authority, Capenhurst.

Valentine, James M., B.Sc., Ph.D., Senior Physicist, Western Regional Hospital Board, Glasgow.

Walters, John, B.Sc., Assistant Lecturer, South West Essex Technical College.

Wilson, Raymond A., B.Sc., Senior Science Master, Penang Free School, Malaya.

Graduates

Baker, Alan C., B.A., Physicist, British Oxygen Co. Ltd., London.

Barr, John R., B.Sc., Assistant Teacher of Physics, George Heriot's School, Edinburgh.

Billinger, Trevor S., B.Sc., Technical Engineer, Bristol Aeroplane Co. Ltd.

Cheetham, Ivan C., B.A., Research Physicist, Dunlop Research Centre, Birmingham.

Davey, James M., B.A., Thermodynamicist, Orenda Engines Ltd., Ontario.

*Elliott, Gilbert, B.Sc., Technical Officer, Imperial Chemical Industries Ltd., Welwyn Garden City.

*Forrest, Geoffrey D., B.Sc., Physicist, Wilcolator Manufacturing Pty. Ltd., Victoria.

Goldsmith, Margaret A., B.Sc., Physicist, Sir W. G. Armstrong Whitworth Aircraft Ltd., Coventry.

Harrison, Geoffrey, B.Sc., Assistant Physicist, Leicester Royal Infirmary.

Humphreys, David A., B.A., Scientific Officer, British Ceramic Research Association, Stoke-on-Trent.

Kenny, Michael J., B.Sc., Cut Thread Development Section, Dunlop Rubber Co., Leicester.

*King, Leonard J., B.Sc., Research Engineer, Electrical and Musical Industries Ltd., Hayes, Middlesex.

*MacLeod, Angus J. M., A.R.T.C.

Macleod, Hugh A. M., B.Sc., Apprentice, Sperry Gyroscope Co. Ltd., Feltham.

Manley, David M. J. P., B.Sc., Scientific Officer, Admiralty Research Laboratory, Teddington.

*Merchant, John, B.Sc., Engineer, Standard Telephones and Cables Ltd., Newport.

*Mitchell, William K., B.Sc., Apprentice, Sperry Gyroscope Co. Ltd., Brentford.

Potter, Anne, M.Sc., Technical Information Officer, Zinc Development Association, Oxford.

Richards, Eric, B.Sc., Senior Physics Master, The Royal Grammar School, Colchester, Essex.

*Ridley, Henry, B.Sc., Technical Engineer, Bristol Aeroplane Company, Bristol.

Rooney, John, B.Sc., Research Assistant, Siemens Electric Lamps and Supplies Ltd., Preston.

Rucklidge, John M., B.A., Scientific Officer, Midland Coke Research Station, Sheffield.

Russam, Kenneth, B.Sc., Assistant Experimental Officer, Department of Scientific Industrial Research.

Singh, Jag J., B.A., M.Sc., Research Student, University of Liverpool (on leave from Education Dept., Panjab Government).

Taylor, Stanley F., B.Sc., Teacher, Acton Secondary Technical School.

West, Eric J., B.Sc., Assistant to Research Engineer, Guest Keen Iron and Steel Co., Cardiff.

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The British Thomson-Houston Company Ltd., requires Graduates in its Research Laboratory at Rugby for interesting and varied development work on new light sources. Successful applicants will be expected, in due course, to carry out independent investigations. Experience of vacuum physics or semi-conductor materials is desirable, but applicants graduating this year will be considered.

Write giving details of qualifications and experience to the Director of Research, British Thomson-Houston Company Ltd., Rugby, quoting reference CM.

The British Thomson-Houston Company Ltd., require **Graduate Engineers** and **Physicists** for the design, construction and processing aspects of magnetron and other electronic valve developments. The work is carried out in close association with a small machine shop and pilot production unit, and every encouragement is given to the development of new ideas. It is work in which both practical and theoretical interests are desired. Applicants should write to the Director of Research, British Thomson-Houston Company Ltd., Rugby, giving their age, qualifications and experience, and quote reference FT.

Institute of Cancer Research invite applications from honours graduates in physics or in a biological subject for Studentships in Biophysics and in Medical Physics tenable at the Physics Department of the Institute of Cancer Research : Royal Cancer Hospital, London, S.W.3. These Studentships will normally be awarded for two years, starting October 3, 1955, and may lead to the M.Sc. degree in Biophysics of the University of London. The grant would normally be at the rate of £400 per annum. Applications should be made with names of two referees, to the Secretary, Institute of Cancer Research : Royal Cancer Hospital, Fulham Road, London, S.W.3, not later than June 30, 1955.

Senior Scientific Officer (Physicist) (minimum age 28) required by Ministry of Supply, **Royal Aircraft Establishment,** Farnborough, Hants., to undertake responsibility for instrumentation of supersonic wind tunnels, a hypersonic tunnel and a shock tube, and development of techniques for measurement and recording.

Qualifications :—1st or 2nd class honours degree or equivalent in Physics and at least three years postgraduate research experience of electronic measurement. Salary within range £970–£1,125 (Superannuable). Women somewhat less. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A169/5A. Closing date July 23, 1955.

Royal Technical College, Salford
Principal :
P. F. R. Venables, Ph.D., B.Sc., F.R.I.C.

The Governors invite applications for the new post of **Lecturer in Physics** mainly for teaching in B.Sc., Grad.Inst.P., A.R.I.C., and similar courses. Candidates should preferably have a professional qualification, university degree or other equivalent qualification. Teaching experience is desirable and industrial, professional and/or research experience will be advantageous.

The appointment will date from 1st September, 1955, or as soon as possible thereafter. Salary will be in accordance with the Burnham Technical Report 1954, namely £965–£1,065 (men) ; £722–£852 + 1/7th differential (women).

For further particulars and forms of application please send a stamped addressed envelope to the Principal, Royal Technical College, Peel Park, Salford 5. Applications should be returned by June 25, 1955.

R. Ribblesdale Thornton,
Clerk to the Governors.

A Company of International repute planning immediate expansion of its programme of Semi-Conductor Development requires a number of **Chemists** and **Physicists** with an interest or experience in transistors, diodes, and material problems associated with these devices. Apply, with fullest details of career and qualifications, to the Personnel Manager, **Standard Telephones and Cables Ltd.,** Ilminster, Somerset.

Research Association of British Rubber Manufacturers has a vacancy for a young male research worker to assist in technological investigations in the laboratories and to take part in operational studies in Rubber Factories. For applicants with a Pass Degree in the physical sciences the appointment will be on the Technical Officer Scale (£475 × 25 – £675) at a starting salary depending on age and experience, and with expectation of promotion to Senior Technical Officer (£600 × 30 – £870) ; candidates having other university or professional qualifications and/or industrial experience will be considered appropriately. The post is suitable for someone wishing to prepare himself for an executive industrial position.

Applications, giving full particulars of age, qualifications and experience, to be sent to the Secretary, RABRM, Shawbury, Shrewsbury, Shropshire.

(*Continued on page vi*)

Physicists

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Louis Newmark Ltd. have a vacancy in their laboratories for a **Physicist** or **Electro-Mechanical Engineer** for development work on aircraft and allied instruments. Applications are invited from persons with a degree or similar qualifications who have had some industrial experience preferably on work with gyroscopes or accelerometers. Good salary and prospects. Apply Personnel Manager, Louis Newmark Ltd., Prefect Works, Purley Way, Croydon, Surrey.

COURSES

Borough Polytechnic
Borough Road, S.E.1

A full-time postgraduate course in Nucleonic Techniques and Measurements will be held at the Borough Polytechnic from September, 1955, to June, 1956. The aim of the course is to provide an introduction to techniques and measurements used in nuclear physics, and is intended for physics or electrical engineering graduates who propose to enter the field of research, design of instruments, radio-isotope applications or reactor instrumentation. Further particulars and application form for admission may be obtained from the Secretary, Borough Polytechnic, Borough Road, London, S.E.1.

THE ROYAL TECHNICAL COLLEGE GLASGOW
Department of
Natural Philosophy
A short Summer Course on
" The Electron Microscope and its Application "

will be held in the above Department from June 27 to July 4, 1955. The course is intended primarily as an introduction to the subject and will consist of lectures and practical classes.

Further particulars and forms of application may be obtained from the Secretary.

ASSISTANTS

Development Department of Electrical Manufacturers (E. London) requires **Senior Assistant** with Higher National Certificate in Applied Physics and varied experience. A good remuneration can be offered to suitable applicant. Write full particulars. Box AV.79, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

UNIVERSITY COLLEGE OF THE GOLD COAST

Applications are invited for the post of **Chief Technician** in the Department of Physics. Duties include supervision and training of laboratory staff, responsibility for apparatus and stores, preparation of lecture and laboratory material for teaching up to B.Sc. (Special) Degree level. Candidates should have either considerable experience of similar work in a University institution or an Honours or Special Degree in Physics. Opportunity for postgraduate research may be provided if a graduate is selected.

Three-year contract in first instance. Salary £1100 per annum with a gratuity of £150 in lieu of superannuation provision. Family allowance £100 per child (maximum £500 per annum). Part furnished accommodation at a rent not exceeding 7.5 per cent of salary. Outfit allowance on first appointment. Annual leave eight weeks in United Kingdom. Passages provided for appointee, wife, and maximum of five children.

Applications (6 copies) with the names of three referees should be sent, before June 20, 1955, to the Assistant Registrar (London), 29 Tavistock Square, London, W.C.1, from whom further particulars may be obtained.

Central Research Establishment, National Coal Board (at Isleworth, Middlesex) invite applications for superannuable appointments on the research staff as **Scientific Technical Officers** Grade II (scale £515 × £20 to £735 male, and £420 × £16 to £596 female), or **Scientific Technical Officers** Grade III (scale £400 × £20 to £560 male, and £325 × £16 to £453 female), depending upon qualifications and experience ; London Location Allowance of £32 10s. 0d. minimum, rising to £50 maximum, is payable in addition.

The work embraces :—(*a*) problems in the control and improvement of working conditions in mines ; (*b*) mechanical properties of coal of relevance to coal winning ; (*c*) technical methods of coal winning ; (*d*) design of experimental coal-getting machinery ; (*e*) technical problems arising in coal transport, roof support, etc. ; (*f*) metallurgy and (*g*) instrumentation of use in mines and laboratory in connection with the above problems.

Much of this work will be carried out initially in the laboratory, although staff may be required to continue their experiments underground. Candidates should preferably have a Higher National Certificate in Mechanical Engineering or Applied Physics, a pass at A level in the G.C.E. with Mathematics and Physics or equivalent qualifications and some experience in research.

Write, giving full particulars (in chronological order) of age, education, qualifications and experience (with dates) to National Coal Board, Establishments (personnel), Hobart House, Grosvenor Place, London, S.W.1, marking envelope TT/980. Original testimonials should not be forwarded. Closing date June 20, 1955.

LABORATORY AND WORKSHOP NOTES 1950-1952

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